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Over-water Simulant Release Testing for the Joint Services Lightweight Standoff Chemical Agent Detector (JSLSCAD)

April 2004

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Abstract:

NSWCDD Has supported the JSLSCAD program through participation in joint IPTs for system development, logistics, and test and evaluation. As part of its role in support of Test and Evaluation NSWC performed over water testing of the JSLSCAD on its Potomac River Test Range in July/August of this year. Testing over water presents several unique challenges, foremost being to question of how to adequately referee the simulant challenge, and how to safely and effectively provide that challenge. By using a combination of Infrared (IR) cameras, and M&S tools coupled to on the spot meteorological observations we predicted cloud track, and attempted to verify cloud behavior. Issues encountered included speed of coordinating met observations, and tests, and the sometimes-volatile nature of weather conditions in the littoral environment.

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FOREWORD

This test report addresses the Navy developmental test (DT) phase for the Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD). Designated DT-IIA and DT-IIB in the Test and Evaluation Master Plan (TEMP), this testing was conducted at the Naval Surface Warfare Center Dahlgren Division (NSWCDD), Dahlgren, Virginia site (NSWCDL) from July 21, 2003 through August 5, 2003.

The JSLSCAD is an ACAT III program and consists of a fully automated detector with scanning capability. The JSLSCAD will be used by all the services and on several platforms. The system tested at NSWCDD was the land based fixed site configuration of JSLSCAD, although in all important signal processing and hardware configuration parameters it is identical to the shipboard application of this system.

The scope of the Navy DT event comprised several tests aimed at verifying that the system will perform as expected in the Navy environment. Among these tests was the over-water testing of the JSLSCAD system, which consisted of challenges using simulants in near-operational conditions. The tests sought to identify operational and technological capabilities and potential limitations of the system and provide data and analysis in support of the decision to certify the system ready for operational test and evaluation.

CONTENTS

ILLUSTRATIONS

TABLES

GLOSSARY

ACAT	Acquisition Category
CBIRF	Chemical Biological Incident Response Force
CIC	Combat Information Center
CL	Concentration (times) Pathlength
CW	Chemical Warfare
DT	Developmental Testing
EA	Environmental Assessment
ETF	Experimental Test Facility
FOR	Field-of-regard
FOV	Field-of-rview
FTIR	Fourier Transform Infrared Spectroscopy
GAA	Glacial Acetic Acid
GPS	Global Positioning System
HAZMAT	Hazardous Material
HPAC	Hazard Prediction and Assessment Capability
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
ID	Inside Diameter
IR	Infrared
JSLSCAD	Joint Service Lightweight Standoff Chemical Agent Detector
MDE	Maryland Department of the Environment
Met	Meteorological
M&S	Modeling and Simulation
NLMOC	Naval Atlantic Meteorology and Oceanography Center
NOAA	National Oceanic and Atmospheric Association
NSWCDD	Naval Surface Warfare Center Dahlgren Division
NSWCDL	Naval Surface Warfare Center Dahlgren Laboratory (site)
ODU	Operator Display Unit
OT	Operational Testing
OTD	Operational Test Director
PA	Power Adapter
PRTR	Potomac River Test Range – approximately 3 x 16 nautical miles
RH	Relative Humidity
SBCCOM	Soldier Biological Chemical Command
SEM	Sensor Electronics Module
SF_6	Sulfur Hexafluoride

SM	Scanner Module
SOP	Standard Operating Procedure(s)
STSTS	Search and track sensor test site
TCP	Transmission Control Protocol
TD	Test Director
TEMP	Test and Evaluation Master Plan
TEP	Triethyl Phosphate
TU	Test Unit
UDP	User Datagram Protocol
VDC	Volts Direct Current
g/L	grams per liter
km	kilometers
μm	micron (10^{-6} m)
mg/kg	milligrams per kilogram
mg/m^3	milligrams per cubic meter
mm Hg	millimeters of mercury
ppm	parts per million

BACKGROUND INFORMATION

The Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD) system detects the presence of chemical warfare (CW) agent vapor clouds at distances up to 5 kilometers (km) from stationary or on-the-move platforms. The system uses Fourier transform infrared spectroscopy (FTIR) technology to detect and classify threats based on their emission and absorption characteristics in the 8-12-μm region of the electromagnetic spectrum. This test report addresses the Navy developmental testing (DT) for JSLSCAD, conducted at the Naval Surface Warfare Center Dahlgren Division (NSWCDD), Potomac River Test Range (PRTR). The purpose for the Navy DT phase was to ascertain the ability of the JSLSCAD system to operate in the maritime environment under near operational conditions. Navy DT for JSLSCAD is required per the Test and Evaluation Master Plan (TEMP). Following the Navy DT phase, and after the operational test director's (OTD) approval, operational testing (OT) will begin.

The Navy DT at NSWCDL consisted of three parts: Part I is the initial checkout, which included laboratory challenges to the detector system; Part II is the over-water test described by this test report; Part III includes all the environmental survivability tests required for shipboard equipment. Part III was terminated prior to completion due to program issues.

Part II of the JSLSCAD Navy DT test phase was abbreviated due to programmatic issues which dictated a pause in the program. The scope of DT Part II was reduced to five simulant releases each with the simulants SF_6, TEP and Acetic Acid. Future tests will be conducted to resolve any uncertainty about the operational effectiveness of this system or its replacement in the eyes of the Navy warfighter.

PARTICIPANTS

Because of the variety of resources needed to carry out the test, many groups within NSWCDD participated in the over-water test event. Other services and agencies were present as observers. NSWCDD-B56, the Chemical, Biological, and Radiological Detection Systems Branch, had primary responsibility for the test event. The entire list of participants and responsibilities is as follows:

NSWCDD-B56. Chemical, Biological, and Radiological Detection Systems Branch responsibilities:

a. Overall planning of the test
b. Write and obtain approval of Standard Operating Procedures (SOPs) for the test
c. Accept and perform initial checkout of Test Items
d. Procure simulants required for test
e. Procure non-dissemination equipment needed for test

f. Coordinate test efforts with other NSWCDD departments
g. Coordinate testing to be performed by outside contractors at their facilities
h. Review Environmental Assessment documentation and coordinate approval

NSWCDD-T43. Special Systems Branch responsibilities:

a. Design, procure, assemble, and test simulant dissemination equipment
b. Operate the test platform (boat)
c. Engineering support (dissemination equipment)
d. Operate the dissemination equipment
e. Collect and relay GPS and other relevant data from the release area

NSWCDD-T44. Technology and Photonic Systems Branch responsibilities:

a. Design and test simulant dissemination equipment
b. Engineering support (dissemination equipment)
c. Analysis support (Environmental Assessment Report)
d. Coordinate and participate in testing at contractor facility
e. Engineering support (test event)
f. Develop and operate "Reference System" to monitor simulant clouds
g. Provide meteorological (met) data from the release boat
h. Provide release boat data from the operational area
i. Coordinate participation of outside M&S groups

NSWCDD-G604. Potomac River Test Range responsibilities:

a. Range surveillance and control
b. Supply meteorological data at NSWCDD Range Control
c. Supply equipment to load and unload dissemination equipment into and out of test vessel

Defense Threat Reduction Agency (DTRA) responsibilities:

a. Modeling and Simulation support
b. Post-test cloud track prediction

Naval Atlantic Meteorology & Oceanography Command (NLMOC) Participation:

a. HPAC, HYSPLIT Runs, and high resolution weather model Meso Scale Meteorological modeling
b. De-conflicting HPAC and HYSPLIT modeling results

National Oceanographic & Atmospheric Administration (NOAA) Participation

a. NOAA mesoscale forecast windfield and HYSPLIT Runs
b. Coordination of M&S Met Modeling with NLMOC
c. De-conflicting HPAC and HYSPLIT modeling results.

OBSERVERS

a. JSLSCAD Army representatives (PM NBC Defense Systems (PM NBCDS))
b. Maryland Department of the Environment (MDE) and their contractors
c. US Army Soldier Biological and Chemical Command (SBCCOM) Scientist.
d. Marine Corps' Chemical Biological Incident Response Force (CBIRF)
e. Physical Sciences Inc. Scientist.

TEST ITEMS

SYSTEM DESCRIPTION

The fielded JSLSCAD system consists of four major components:

- Scanner Module (SM). Covers a Field-of-regard (FOR) of 360º azimuth, and 60º (−10º + 50º) elevation.
- Sensor Electronics Module (SEM). Optics and electronics that make up the detector. Includes embedded signal processing.

The SM and SEM are fastened together and commonly referred to as the SM/SEM unit .

- Operator Display Unit (ODU). The computer display that provides threat information to operator, and provides control interface to the detector unit (SM/SEM).
- Power Adapter (PA). Provides 28 volts direct current (VDC) (converted from 115Vac) to the SEM.

The operational shipboard configuration, referred to as the dual configuration, will consist of two SM/SEM units, two PA units, and two ODUs. The system is controlled via the master ODU (when deployed to the fleet, the master ODU will be located at Combat Information Center (CIC). The second (slave) unit will be located on

the bridge.) The ODU also displays information regarding threat cloud location (bearing) and the type of threat (blister, nerve, blood).

Each test article for the Navy DT test phase consisted of one SM/SEM, one ODU, and one PA. During the Navy test phase the JSLSCAD "single configuration" was used to avoid schedule delays, allow simultaneous tests, increase the number of observation points, and maximize data collection in general.

SYSTEM OPERATION

The JSLSCAD system detects the presence of a vapor cloud by collecting the energy that enters its 1.5º field-of-view (FOV). The energy collected is in effect the relative temperature differential between the target cloud and the background at each sampled wavelength; the vapor cloud may absorb or emit energy in the infrared (IR) region of the electromagnetic spectrum. A large temperature difference between vapor cloud and background will significantly enhance detection sensitivity. Sensitivity is expressed in terms of concentration length (CL), which is defined as the average concentration of the cloud multiplied by the effective cloud path length:

$$CL = \text{Concentration}_{avg} \text{ X Path Length}$$

Thus, if the cloud is large, the path length will be long and detection can be made at lower concentrations.

Specialized software algorithms, which recognize spectral features in real time, have been developed for JSLSCAD. Data are filtered directly through a discriminating algorithm to eliminate the effects of changing background and to determine if agent is present. The algorithm will also disregard common interferents, such as smoke, diesel emissions, and fog oil; however, dust, IR smokes, snow, rain and water vapor are all obscurants that may prevent detection or reduce the effective range of the system.

When the system detects a threat, it will sound an alarm, and display threat information on the ODU. The left and right edge location of the cloud (heading), and the top and bottom (elevation) will be displayed on the screen, as well as the agent type. An operator will relay the information to the Commanding Officer to make decisions regarding contamination avoidance maneuvers, protection levels, and combat effectiveness.

Figure 1 JSLSCAD SEM and Power Adapter (lower right)

Figure 2 JSLSCAD Operator Display Unit (ODU)

OVER-WATER TESTS

OBJECTIVES

The purpose of the test was to determine if the JSLSCAD system will function as expected when operating over water. The testing was conducted on four detector units. Objectives were as follows:

1. *Demonstrate* the system's simulant detection and differentiation capability outdoors in an over-water environment.
2. *Demonstrate* the system's capability to operate under near-operational conditions, and readiness for OT.
3. *Collect* data to complement OT data.

EQUIPMENT

There were four JSLSCAD systems deployed at the PRTR for these tests. They were at three locations, two on land and one on a test boat operating on the water.

To demonstrate simulant detection and differentiation, simulant vapors were disseminated over water using the research vessel, Gatlin, as the simulant release boat equipped with the vapor generating equipment described below. The Gatlin also carried

equipment on board to provide meteorological and GPS information. Vapor generation equipment consisted of the following:

For Acetic Acid, TEP:

- Simulant tank. Simulant was released from a stainless steel tank previously hydrostatic tested to 300 lbs, located on deck and loaded with enough simulant for one test run. The tank was equipped with valve and regulator controls to regulate its pressure, and the flow rate of simulant during release. Compressed Nitrogen was used to pressurize the tank to about 200 psi. A ½-inch inside diameter (ID) stainless steel line carried the simulant from the pressurized tank up to the nozzle system.

- Stack. A 40-foot aluminum pipe stack, 24 inches in diameter, was installed on deck in the aft section of the vessel atop the blower. The stack directed the air from the blower vertically and generated air velocities of approximately 120 mph.

- Nozzle. The atomizing nozzle (Spray Systems Co. "Flowmax – 01") system generated an aerosol from the liquid simulants. The nozzle requires a compressed nitrogen source to help shear the droplets within the internal mixing chamber of the nozzle. Two ½-inch ID stainless steel lines go up the outside of the stack to the nozzle mounted on top of the stack at the outlet. One delivers the liquid simulant to the nozzle and the other carries the nitrogen gas.

- Blower. A 38,000-CFM blower (Twin Cities Fan Companies, Ltd.) powered by a 100-hp diesel engine (John Deere) generated the airflow to project the simulant vertically approximately 60 to 80 feet past the top of the stack.

For SF_6

- SF_6 was supplied as a compressed gas, and as such did not require additional pressurization. The dissemination setup differed from that of the liquid simulant in that the simulant spray tank was not used.

  The output from the SF_6 compressed cylinders was delivered to the simulant release stack by discharging the SF_6 bottles directly into the intake of the blower. This approach was adopted after it was found that using the same transfer lines used to deliver the liquid simulants did not permit adequate flow of SF_6 to release the desired quantity of simulant in the time required.

Figure 3 Dispersal Stack and Blower on Simulant release boat Gatlin

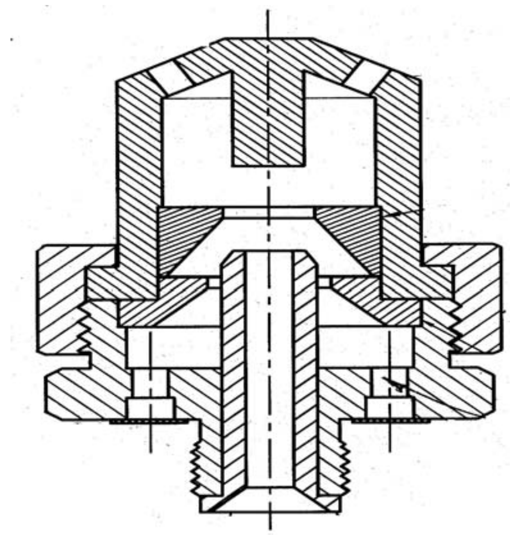

Figure 4 Simulant Dispersal Atomizing Spray Nozzle

A total of four test articles were provided to NAVSEA for DT. Two were installed at the land based test command post, one at another land based location (AA Fuse), and one on the boat (Sealion) designated for sensor and meteorology balloon deployment for over-water test.

Procedure

Overview

Four single-configuration JSLSCAD units were tested for simulant detection and identification at NSWCDL on the Potomac River Test Range. The tests consisted of five releases of each of three simulants from a test vessel equipped with the vapor generator. The tests were conducted under varying conditions of weather and distance. The simulant was released in *line releases* along a predetermined course. Each TEP and Acetic Acid release was of 5 gallons of liquid simulant. The first SF_6 release was of approximately 80 pounds of simulant, the second of approximately 59 pounds, the third of approximately 100 pounds, and the two remaining releases of 120 pounds each.

The JSLSCAD systems were stationed two on land at the Search and Track Sensor Test Site - Experimental Test Facility (ETF), one on land at the AA Fuse building and one on a boat operating upwind or cross wind from the simulant cloud. IR Cameras were co-located with one of the JSLSCAD units at the ETF, and with the JSLSCAD unit on the Sealion to track the position of the simulant cloud.

Figure 5. Simulant Release Boat Gatlin operating on the PRTR

Pre-test modeling of projected simulant clouds based on the test parameters chosen and representative weather conditions for the time of year indicated that, depending on wind conditions, if the cloud is defined as the contour within which the concentration is greater than or equal to 10 mg/m3, then the initial simulant cloud set up for the liquid simulants (TEP or GAA) would be at least 100 m long, and from 50 to 100 m wide at 2 - 4 minutes after release. Similarly an SF_6 release of 125 lbs would be expected to yield a 10 mg/m3 contour of approximately 140m x 250m for a representative set of meteorology conditions.

Prior to each release an initial modeling run based on surface meteorological conditions was used to select the release point. Once the simulant release and detector boats had arrived on station, a surface marker was deployed and the Latitude/Longitude of that point recorded to mark the release location. A set of surface meteorological observations was relayed to the modelers and another run was made to confirm the anticipated cloud track. Then, a met sonde was deployed by weather balloon to obtain a vertical profile of the atmosphere; wind, temperature, RH and barometric pressure. These conditions were collected over an approximately 2000 meter vertical path. The Modeling and Simulation (M&S) tools used this pre-test data to furnish a projected track of the simulant cloud, and post-test to estimate the CL of the cloud released. Surface meteorological conditions were also recorded immediately post release to help with post-test analysis.

Test Day Schedule

Each test event was highly dependent on weather conditions. For this reason local weather conditions were monitored very closely, beginning on the day before each test. Based on 18 hr (the evening before) and 2 hr pre-test weather predictions the decision was made to proceed to test. The schedule for a typical test day was as follows:

Time	Event
(16-18 hr prior)	Go / No-Go Decision - first weather forecast
-0600	Pre-test hazard brief and test scenario review (T –2 hr)
-0630	Preparations for TD to notify all players Go for test (T-1 hr)
-0645	Boat to simulant release area (T –30), range boats secure test area
-0753	Radio check
-0747	Simulant release boat reports surface met conditions
-0810	HPAC prediction from M&S team
-0815	Simulant release boat deploys lat/long marker
-0830	Release met sonde - sonde data transmits to main range
-0848	Final HPAC prediction from sonde data
-0930 - 0932	Simulant release 1 (T –0)
0932 – 0942	JSLSCAD units record data for 10 minutes post release
0950	Declare range clear 20 minutes post release, notify Range Control
-1000	Boats return to Yardcraft (T ±30 min, approx)

Table 1 Typical Test Day Schedule

Operational Area

The operational area for the over-water test is pictured in Figure 6. The area is divided into four quadrants: N, S, E, and W. These quadrants were used as starting points, depending on wind conditions. Buoy 29 was used as a general reference point for the boat when assuming its starting position. All tests were conducted in accordance with the requirement that testing must be maintained inside the PRTR limits, a minimum of 4800 yards upwind of any shoreline, and no further than 5–6 km down river from Range Control. The test vessel could not operate in less than 8 feet of water.

Start Area. Specific start areas were designated for simulant release. These areas were selected to maximize cloud dwell time over water, and to maintain a minimum distance of 4800 yards upwind of any shoreline. Wind condition was considered before selecting the start area.

Wind direction (from)	Start area	(boat)Heading
SW	N or E Quad	SW
N	S or W Quad	N
NW	S or E Quad	NW
S	N,E or S Quad	S
NE	W or S Quad	NE (NO-GO at less than 3-km range)
SE	N, E or S	SE

Table 2 Boat Heading and Start Point vs. Wind Direction

The exact heading of the boat was determined in the pre-test brief.

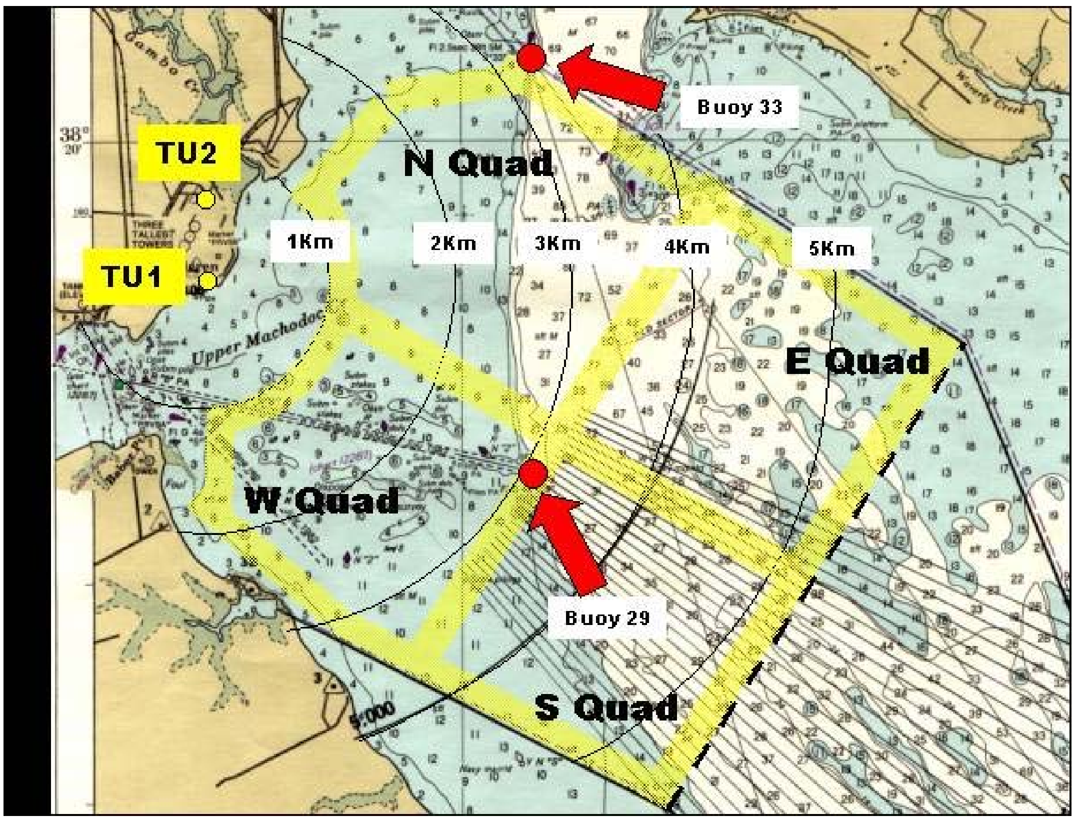

Figure 6 Testing Area—Potomac River Test Range (PRTR)

Test Matrix: The test matrix below shows the SF_6, TEP and Glacial Acetic Acid (GAA) releases conducted over the test period of 21 July through 05 August. During this test period we experienced two no test days due to weather conditions and some minor delays due to equipment problems and availability of the range.

Because of performance at other test sites, and other issues experienced by the program we were asked to restrict the tests to five releases with each simulant, and to restrict the range to 2 km or less.

Test Matrix (Truncated to 5/simulant) with release times

Simulant Release	Start Date	Release Time	Qty released
SF6 - 1	7/21/2003	09:20:00	27.2 kg
SF6 - 2	7/24/2003	10:22:00	36.3 kg
TEP - 1	7/24/2003	16:30:00	15.76 kg
SF6 - 3	7/25/2003	11:02:00	42.2 kg
TEP - 2	7/25/2003	12:30:00	22.3 kg
SF6 - 4	7/28/2003	08:50:00	54 kg
TEP - 3	7/28/2003	10:05:00	21.6 kg
SF6 - 5	7/30/2003	08:15:00	54 kg
GAA - 1	7/30/2003	10:35:00	21.8 kg
GAA - 2	7/31/2003	13:55:00	21.8 kg
TEP - 4	7/31/2003	14:46:00	22.3 kg
GAA- 3	8/01/2003	12:50:00	>20kg
GAA - 4	8/04/2003	09:00:00	18.7 kg
TEP - 5	8/04/2003	10:15:00	22.6 kg
GAA - 5	8/05/2003	10:04:00	19.8 kg

Table 3 Matrix of **s**imulant releases conducted

Meteorological Conditions

Meteorological conditions required for testing were limits specified in Table 4. These conditions represent optimum conditions to prevent the cloud from dispersing too soon and to keep the cloud away from the test vessel and crew. The meteorological conditions for each release are listed in table 5.

Parameter	Limit
Wind Speed (Sustained)	10 knots (max)
Wind Direction	Between NNW and WNW preferred, other directions may be acceptable in light wind conditions.
Wind Gust	12 knots (max)
Rain	No Precipitation

TABLE 4. ACCEPTABLE WEATHER LIMITS FOR TEST CONDITIONS

Release	Simulant	Time of obs (min)	Wind speed (m/s)	Wind Direction (°,True)	Barometric (mbarr)	Temp. (Celsius)	RH (%)	Local Time (Hr Min)	Duration (min)	Release amount (Kg)	Simulant Release Pt. Lat.	Long	Sky State
16jul03H2O	Water		3.05	202	1015.1	26.7	70.1	1130			38* 18'	76* 59'	Partly cloudy
21julSF601	SF6		5.7	208.6	1012.8	26.5	75.1	912	13	36.2	38°18'	76°59'	vis 2miles in haze no overcast
24julSF602	SF6	T +7	3.1	271.6	1017.2	22.6	62.7	1022	3	26.8	38*19'	77*00'	9/10 cover vis 10 miles
24julTEP01	TEP	+10	5.09	126.4	1017.8	26.5	error	1624	1.5	15.76	38*18'	77*01'	clear vis >10miles
25julSF603	SF6	+53	1.4	340.6	1025.4	25.9	58.5	1103	6	42.2	38*18'	76*59'	clear vis >10miles
25julTEP02	TEP	+10	1.6	45.7	1025.5	26.9	42.6	1238	2	22.3	38*20'	77 * 00'	clear vis >5miles
28julSF604	SF6	+12	2.88	270.4	1012.7	27.1	67	849	6	54	38*19'	77*01'	9/10 cover vis >5 miles
28julTEP03	TEP	+7	1.66	296.6	1012.7	27.5	67.5	1001	2	21.6	38*19'	77*01'	9/10 cover vis >5 miles (rain moving in fast)
30julSF605	SF6	+19	4.1	37.4	1020.2	22	83	814	6	54	38*19.7'	76*59.2'	10/10 cover vis 3 - 5 miles
30julGAA01	GAA	+7	5.4	120.1	1021	22.2	71.03	1036	2	21.8	38*19.6'	76*59.4'	solid overcast
31julGAA02	GAA	+20	0.74	248.5	1020.2	25.1	72.7	1354	2	21.8	38*19.6'	76*59.7'	8/10 cover vis < 5miles (clouds on horizon with center (overhead) break-thru)
31julTEP04	TEP	+6	2	173.5	1020	25.1	74	1446	2	22.3	38*19.6'	76*59.7'	7/10 cover vis < miles (hazy)
01augGAA03	GAA	+14	2.8	238.3	1017.5	27.6	72.7	1250	2	>20 Kg *	38*18.7'	77*00.4'	10/10 cover Hazy vis 3 miles
04augGAA04	GAA	+5	2.8	224.3	1016	23.4	92.6	900	2	18.7	38*18.6'	77*00.2'	3/10 cover vis = 10 miiles
04augTEP05	TEP	+5	2.4	168.6	1016	24	91.3	1015	2	22.6	38*18.9'	76*59.3'	Overcast 5 miles (hazy and cloud covered. Rain present at T+7)
05augGAA05	GAA	+5	6.3	264.9	1013.1	22.1	89.90	1004	2	19.8	38*19.03'	77*00.7'	overcast 3 miles (rain preceeded release)

* Lost Flow meter - manual positioning of valve - More than 5 gal in tank.

Table 5 Weather conditions during each release.

Conclusions:

A total of 15 simulant releases were conducted on the Potomac River Test Range between 21 July and 5 August 2003. Data from these tests will be used in evaluation of the JSLSCAD and determining its readiness for future tests. The tests were conducted without incident and with no discernable impact on the local environment.

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